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University of Vermont  
Burlington, Vermont

PROGRESS REPORT NO. 2

to

National Aeronautics and Space Administration

Grant NRG 46-001-008

For Period August 1, 1965 to January 31, 1966

Dr. Clinton D. Cook  
Vice President for Academic Affairs  
Director of Space Science Program

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The first year of the Space Science Program under the support of the NASA Sustaining Grant has been most successful. The grant has not only stimulated graduate training and research in a number of academic departments of the University but also has served as a catalyst in bringing together on a common project individuals from diverse disciplines. In Progress Report No. 1 the unique geographical situation of the University with all colleges located on a single campus of moderate size was mentioned. The desire of the University to capitalize on this asset through strong interdisciplinary programs of graduate education and multidisciplinary attacks on research problems has been furthered by the NASA Sustaining Grant in nurturing a number of interdisciplinary projects.

This report is essentially a continuation and updating of Progress Report No. 1 (October 30, 1965) describing primarily the accomplishments during the period August 1, 1965 to January 31, 1966. During this period funds available were not sufficient to initiate any new projects. Proposed new projects for the coming year have been described in the proposal submitted November 7, 1965.

Notable progress has been made by Dr. Roth in his attempt to extract more information from radiographs by conversion of density scales to color scales with the display of the color encoded radiograph on a color TV screen. This technique will be ready for clinical evaluation as soon as improved resolution can be obtained; the commercial TV system now in use is not sufficiently refined. Dr. Roth describes his work more completely in his progress report. Copy No. 1 of this report contains a color photo of a color encoded radiograph as seen on a commercial TV screen.\*

Dr. Donald G. Forgays, in his progress report on isolation studies indicates that pilot tests have been made on the controlled temperature water bath with associated control, monitoring equipment, air supply and intercom now ready for use. Examination of some 300 literature references indicates that a number of other investigators of isolation by water bath have not had satisfactory environmental control and it is hoped that the refinements made by Dr. Forgays will make it possible to obtain significant results under well controlled conditions.

\*Photographs suitable for reproduction were previously submitted to Mr. Edward Redding.

Seven of the projects which were begun during the first year of the grant will be continued into the second year. The Executive Committee is satisfied that these projects are being well carried out and show promise of producing interesting results. These projects with amounts allocated for the next four to six months of operation are:

1. Instrumentation and Model Facility	\$ 10,000
3. Residual Stresses Resulting from Sudden Heating; Howard Duchacek, Principal Investigator	8,065
4. Individual Differences in the Influence of Sensory Isolation upon Intellectual, Emotional, and Physiological Functioning; Donald G. Forgays, Principal Investigator	7,025
6. Effect on Brain of Current from External Electrodes; Wilbert F. Chambers, Principal Investigator	5,826
7. (7A) - Bioenergy Electrical Sources; (7B) - Radiological Data Processing; Wilfred Roth, Principal Investigator	8,448
8. Computer Applications in Clinical Pathology; Rex D. Couch, Principal Investigator	21,726
12. Entropy Determinations; Claus A. Wulff, Principal Investigator	<u>4,600</u> \$ 65,690

In the list above Project 1, Instrumentation and Model Facility, requires further explanation. During the first year of operation some support was given to the Unified Engineering Shop for the purchase of certain machine tools required for the support of research projects. The Executive Committee has assigned support under the same project budget during the second year for equipment purchases for the newly established Instrumentation and Model Facility which will provide services for research projects all over the campus. The establishment of this facility is an important step forward in providing the necessary tools and manpower to make and service the many special pieces of equipment needed in research. This facility eventually will be located on the first floor of a wing of the new Life Sciences Building for which construction will start this spring. The facility, equipped and supplied, will cost \$250,000 to \$300,000. The allocation from NASA funds will provide certain needed pieces of equipment for research support. The other projects have been described before in previously submitted proposals and the status of each will be found in the individual progress reports later in this report.

Two additional projects were recommended for support by the Executive Committee. These are:

13. Energy Band Quantization in High Electric Fields Lloyd M. Lambert, Principal Investigator	\$ 10,820
14. Analysis of Compartmental Models by Means of Hybrid Computers; Charles F. Taylor, Principal Investigator	<u>5,549</u> \$ 16,369

These projects were described in the proposal submitted December 3, 1965.

For the present, support has been withdrawn from the following projects:

2. Experimental Study of Photoelectric, Optical, and Surface Properties of Transition Metals;  
David W. Juenker and Albert D. Crowell, Principal Investigators
5. Smooth Muscle Activity as Recorded by Radio Telemetry;  
Kenneth R. Simmons, Principal Investigator
9. Dimension-Theoretical Aspects of Metrizable;  
Bruce R. Wenner, Principal Investigator
11. Lehrman-Symanzik-Zimmermann Formula as a Computational Technique in Field Theory;  
Leonard M. Scarfone, Principal Investigator

Continued funding of the above projects was recommended by the Executive Committee only in the event that sufficient additional funds are available during the year beginning February 1, 1966. While it is possible that other projects being supported may secure support from other sources and thus release funds which can be used to reactivate these projects, it is likely that they will not be reactivated unless additional funds are received from NASA.

Of the projects initiated during the first year one project, No. 10, for which support was provided no longer required support. While Dr. Hyde will continue to use the equipment provided by the grant in his research from the standpoint of funding, the project will be considered completed and the progress report will be considered a final report. This project is:

10. Electron Microscopy; Beal B. Hyde, Principal Investigator

At the time this report is being prepared there is unallocated approximately \$17,941 of the \$100,000 granted for the second year, since funds have been allocated for the remainder of this semester only. It should be pointed out, however, that to continue the presently active projects to any significant extent beyond June will be impossible without additional funds. Furthermore, the projects for which support has been suspended cannot be reactivated except to the extent that funds are provided in excess of the \$150,000 annual level established for the first year.

In summary. Results of the first year of operation have been most rewarding and significant progress has been made. Demands for funds for the support of worthwhile projects greatly exceed the support available.

### Individual Project Reports

In the following pages will be found progress reports as submitted by the principal investigators for each NASA supported project through 12, with the exception of reports on Projects 1 and 11. Project 1 was established for budgetary purposes only to cover the purchase of equipment for the Engineering Shop; Progress Report No. 1 contained a report on this activity and no further report is needed at this time. Project 11 was completed during the summer of 1965 and the final report was contained in Progress Report No. 1.

PROJECT II - EXPERIMENTAL STUDY OF PHOTOELECTRIC, OPTICAL, AND SURFACE  
PROPERTIES OF TRANSITION METALS

Investigators - David W. Juenker, Associate Professor, Department of Physics  
Albert D. Crowell, Professor, Department of Physics

Progress Report - February 1, 1966

Photoelectric and Optical Studies

It has been determined that the first step in this project should be an investigation of a polished (110) (close-packed) surface of a tantalum crystal, with illumination incident at a constant  $45^\circ$  angle, and with the incident plane of polarization as the continuous experimental variable. The sample has been made available by colleagues in another laboratory. The technique referred to is novel, and the exploration of its usefulness has been undertaken as the topic of an M.S. dissertation by Mr. Joel Ross, a NASA graduate trainee in this department.

The experimental method has several attractive features. Principal among them are these, that with a fixed angle measurement and variable polarization, a simple two-window vacuum enclosure suffices to house the specimen, and that the specimen, its enclosure, and the circuitry required for low-level photoelectric current measurement, can all be held stationary. Besides simplifying optical alignment and electronic procedures, the latter feature permits continuous high speed vacuum pumping, which will be a particular asset in later thin film investigations.

The choice of  $45^\circ$  as the fixed angle of incidence of the radiation at the specimen surface permits the intensity of reflected light - from which the optical constants of the sample are to be calculated- to be measured in relative units, since for the two principal planes of polarization, perpendicular to, and parallel with, the plane of incidence, the reflectances at  $45^\circ$  are simply related by  $R = R^2$ . Rotation of the plane of polarization is accomplished by mounting the entire optical assembly, including light source, monochromator, focussing mirrors, and polarizer, on a turntable which can be rotated about the light beam incident on the sample. Perpendicular to that axis the reflected light, now elliptically polarized, enters an end-window photomultiplier, which detects total reflected intensity as a function of the angle between the plane of polarization and the plane of incidence. For metals like those in the transition group, neither of the optical indices  $n$  and  $k$  is much smaller than the other in the visible or near ultraviolet (as occurs, for instance, with aluminum, and with the alkali and noble metals). Hence the variation in reflectance alluded to above is expected to be sufficiently pronounced to admit digital analysis in terms of the values of  $n$  and  $k$ .

Perhaps simultaneously with the reflectance determinations in the ultraviolet, but at least without altering the position or ambient condition of the sample, variation of the photoelectric yield of the sample can be recorded. Together with the knowledge of the optical constants, that variation can be given a probable interpretation in terms of the relative effectiveness of the radiant electric field components normal and tangential to the emitting surface,

and hence in terms of the photoelectric excitation mechanism. It is intended to collect the photoelectrons on a planar electrode, suitably perforated to pass the incident and reflected light beams, and situated parallel with the sample plane. A pair of small Helmholtz coils external to the vacuum tube will produce a magnetic field normal to those planes sufficient to confine the most energetic photoelectrons to the interelectrode space. Such collimation makes possible a simple retarding potential measurement of the normal energy distribution of the emitted electrons.

While it was expected that at least some of the optical data discussed above would have been available from the first specimen by the time of this report, unforeseen delays have prevented it. At present writing the vacuum and electrical systems have been completed and are operating well, and only the optical assembly and the mounting of the sample itself remain to be completed before data can be taken.

### Surface Studies

The apparatus for the study of the effects of carbon monoxide on the electrical resistance of thin metal films has been constructed and preliminary tests are underway. The design represents an advance in that previously reported in the M.S. thesis of Mr. T. Ansbacher by permitting a measurement of the rate and amount of gas adsorption by the film. This observation is made by a molecular-flow-through-a-capillary technique. Studies on a series of metals is to be undertaken, including both transition and other metals. The initial observations are being made on silver.

The effects of carbon monoxide on the photoelectric emission of electrons from a polycrystalline molybdenum surface have been studied by Mr. J. D. Clewley. Using surfaces exposed to (1) argon ion bombardment and to (2) ion bombardment followed by annealing, the changes in Fowler plots of the electron yielding wavelength of incident radiation were obtained. These plots showed that on an annealed surface the rate of change of work function kept up with the rate of bombardment by CO molecules and that there was essentially no change in the probability of photoemission per photon. On the unannealed surfaces, the change in work function was much slower, and there appeared to be changes in the probability of photoemission per photon as well as changes in work function. The differences in the behavior of the two surfaces is attributed to a greater defect density in the latter case. An M.S. thesis describing these results is in preparation and copies giving complete details will be sent to NASA.

The construction of apparatus to observe the amount of adsorbed gas on small metal surfaces by a radio tracer method has continued. Since the last report, a mica window ( $3.0 \text{ mg/cm}^2$ ) has been sealed to the experimental tube and tested for strength and vacuum leaks. The original tube has also been modified to permit ion bombardment of the surface as well as heating by electron bombardment.

**PROJECT III - NUMERICAL METHOD FOR DETERMINING THE RESIDUAL STRESSES RESULTING FROM SUDDEN HEATING OF THE INNER SURFACE OF A SHORT HOLLOW CYLINDER**

Investigator - Howard Duchacek, Associate Professor, Department of Mechanical Engineering

Progress Report - February 1, 1966

**Work Time Assignment**

Research on the above project began in April, 1965 with the assignment of Professor Howard Duchacek to the project for one-quarter of his academic program for the months of April and May. During the summer of 1965 graduate students, Timothy L. Brosseau and Robert B. Lee joined the project for 13 weeks of the summer and were supervised by Professor Duchacek on a one-quarter of one-ninth basis. Beginning September 1, 1965, the graduate students were on a half-time academic basis supervised by Professor Duchacek on a one-quarter academic basis joined by Professor Erling Chamberlain also on a one-quarter time basis.

**General Nature of the Problem**

The problem of thermal shock which is associated with the sudden heating of the inner surface of rocket nozzles is a feature of the space program which needs to be considered further. The solution of this problem for at least one design requires a large mass and requires the use of very costly material. The requirement for the material to withstand high temperature and also have high thermal shock resistance is a demanding one. The occurrence of thermal shock is brought about by a sudden heating of the inner surfaces of rocket nozzles and the condition becomes critical usually within the first one or two seconds after light-off. The condition is developed generally by expansion of the material on the inner surface of the nozzle which is being heated, however, during the same time, the material in the outer portion of the nozzle is relatively cold. This condition develops compressive stresses near the inner surfaces of the nozzle and generally tensile stresses in the other regions of the nozzle which have not as yet been heated. The ductility of the material in question is of prime importance, however, materials which generally withstand high temperatures are very often brittle at usual atmospheric temperatures. Some of these materials exhibit a sudden change from a brittle to a rather ductile condition at a particular elevated temperature known as the brittle-ductile transition temperature, and once the nozzle has been heated to a temperature greater than this critical temperature, there is no longer a problem. Within these first one or two critical seconds after light-off, the problem is complicated by an elastic-plastic condition of stress in the region of the nozzle near the inner surface, and, of course, conditions are changing rapidly with time. It seemed likely that a classical approach to the problem would be extremely unwieldy, hence it was proposed that a numerical method be devised that would determine both the critical stresses of thermal shock, and also would be extended so that residual stresses which remain within the structure after it has cooled would be determined. The second objective was to propose a method that would help to specify the temperature distribution in a cylindrical ring which is of immediate importance to the numerical method. The third objective was to attempt the

correlation of the above mentioned numerical method with an experimental program having to do with the sudden heating of the inner surface of rings.

### First Objective

The numerical method for determining the thermal stress analysis in a hollow ring involves knowing the temperature distribution through the ring thickness at very small intervals of time after the start of heating of the inner surface. It is assumed that there is a condition of unequal bi-axial stress with negligible stress in the axial direction. The further assumption of a uniform heat flux at the inner surface and the use of cylindrical coordinates simplifies the analysis. For approximate analytical purposes, the ring is regarded as a series of concentric cylindrical shells, each of which is described by a value of temperature, radial stress, and tangential stress, ultimate stress, modulus of elasticity, and coefficient of thermal expansion. The geometric constraints together with the standard stress-strain formula furnish means for inferring the radial stress in any given shell once the stress-strain conditions are known for all the shells interior to the one in question. Once this radial stress is known, all other parameters for this shell are computed by application of relevant formulae as also is the radial stress versus radius curve becomes zero at the inner and outer radii of the ring. The computer program exploits this fact by having the computer operator feed in intelligent guesses as to the radial stress gradient near the inner surface, calculating the condition (i.e., values of the parameters) in successive concentric shells resulting from a given guess and finally displaying the value of radial stress at the outer surface which must be equal to zero. This value is accepted or not as the operator considers it to be a good approximation to zero. If this value is rejected, the operator modifies his guess as to the inner-most radial stress gradient. Once the condition of zero radial stress is obtained at the outer surface, the stress-strain value calculated for the successive shells are taken to be the real ones.

With these values recorded, the new temperature distribution is introduced. Any plastic action due to the combined effects of the just calculated stress-strain distribution and the temperature variation is permanently incorporated into the dimensions of the shells, and when this is done as the cycle is repeated (i.e., a new value for radial stress gradient at the inner surface is guessed, and a new stress-strain distribution is obtained as above).

The computer program for the method as described above has been written, satisfactory computations have been made for the first time instant, and further de-bugging of the program needs to be completed for additional time instants.

### Second Objective

The second objective, which is to determine a method to specify the temperature distribution in the cylindrical ring, has also received active attention. A plasma jet is to be used as the heat source for the rings because of its capability for sudden application of very high temperatures, its adaptability to a timing mechanism, for reproducibility of heat flux, and for relatively low power drain. Nitrogen plasma is deflected from the end of a

carbon rod to the inner surface of the ring. The ring used in this particular experiment is one of copper because of its very high thermal diffusivity and consequent high resistance to the melting of the inner surface of the ring when the ring is cooled on the outer surface. Thermocouples were fastened to the ring at several radial locations and temperature distributions were obtained at some radial locations on the copper ring. Initial data from this experiment was found to have a non-uniform heat flux at the inner surface of the ring owing to erosion to the end of the carbon rod upon which the nitrogen plasma was sprayed. This condition has been corrected by causing the carbon rod to be rotated, and this together with considerable care in centrally locating the plasma jet appears to have overcome this problem.

In order to determine the heat flux and also the temperature distribution at several instants of time after light-off, temperature distributions were plotted at these several time instants and the heat flux was obtained by a determination of the temperature gradient of the inner surface. The problem is complicated by the difficulty of inserting thermocouples close to the inner wall. The classical determination of radial temperature distribution in a long hollow cylinder is well documented, and the method of finite differences was employed with this equation to determine temperature curves which would match the experimental curves. The theoretical curves gave a somewhat smoother temperature gradient close to the inner surface and will enable a more accurate determination of heat flux at this inner surface at several instants of time after the light-off. After determination of the heat flux, an attempt will be made to determine the temperature distributions without recourse to experimentation.

### Third Objective

The third objective which included a proposal to conduct an experimental program to determine the temperature and strain during the heating cycle and the residual strain upon return to ambient temperature has not as yet been started. Pressed and sintered tungsten rings have been ordered for this experimental program, and a strain measuring device is in the process of being designed. However, it is estimated that intense application of effort on this part of the program will occur in the early part of the summer of 1966.

In general, the first two objectives of the proposal are being actively pursued. The third objective of the proposal will be attempted during the early summer of 1966.

PROJECT IV - INDIVIDUAL DIFFERENCES IN THE INFLUENCE OF SENSORY ISOLATION  
UPON INTELLECTUAL, EMOTIONAL, AND PHYSIOLOGICAL FUNCTIONING

Investigator:- Donald G. Forgays, Professor, Department of Psychology

Progress Report - February 1, 1966

This study has been underway for approximately ten months. During that time principal attention has been directed to two tasks; literature search and technical problems of subject immersion. Progress on these tasks has been made, as follows:

1. An essentially complete review of the pertinent literature has been made. There are about 300 relevant titles; these have been read and abstracted. An article reflecting a review of this literature is being prepared it will be submitted for publication some time during the next reporting period. The review indicates that there have been very few isolation studies in which adequate controls have been employed or even in which much systematic variation of conditions was attempted. This has likely reflected the extreme difficulty in achieving adequate base conditions of sensory isolation.
2. The technical problems of subject immersion were many but all have been solved to date.
  - a) Gravity heat (large radiators and a small isolation room) was used initially to maintain the room and the water in the tank at body temperature. This proved to be too variable. Thus a large coiled immersion heater has been designed and is being fabricated for delivery in February.
  - b) An attempt was made to avoid filtering of the water by substituting replacement of the water on a frequent basis. With the water at approximately 100 degrees F, however, fungi grow at a rapid rate. We have designed and ordered an appropriate filtering system and have set up a water chlorination scheme and frequent testing of the water.
  - c) We have set up a two way communication system between the subject in the tank and the experimenter outside of the isolation room. A microphone has been built into the breathing headset and there is an underwater speaker built into the tank. Several technical problems had to be resolved before this system was functioning properly.
  - d) Problems of recording physiological functioning underwater have occupied our attention over the past two months. Methods have been worked out for measuring such things as respiration, EKG, EEG, PGR, etc. underwater.
  - e) Our review of the literature indicated that submersion in water over an hour or two would lead to minor renal changes resulting in an increased production of urine. To avoid discomfort to our subjects, they are being equipped with elimination bags which are strapped to the leg. Since we are collecting the urine from the isolated, submersed subjects, we will undertake urinalysis systematically and make these measures part of our physiological studies.

3. Over the past year we have added to the project the part time help of two persons
  - a) Dr. Ernest D'Angelo is a physician taking his residency in the Division of Otolaryngology, College of Medicine, University of Vermont. During the present year of his residency, he is undergoing research training in the Department of Psychology. His contribution to the project is in providing continuing medical supervision of the experiments. Each volunteer subject is examined medically before being accepted to participate. He is also examined again immediately before submersion and at periods after leaving the isolatory experience. Dr. D'Angelo is present throughout the submersion period of any subject as well.
  - b) Mr. Richard Blanchard is an electrical engineer who has been functioning as a research assistant in the Department of Anatomy of the College of Medicine, University of Vermont. He has contributed importantly to the development of the physiological indices underwater and the two-way communication system.
4. We have submerged several persons in the tank for varying periods of time, up to 1/2 hour. The experimenters served as subjects. Our plan is to continue to submerge the experimenters for periods up to six hours (the maximum period for experimental subjects). This routine will persist until we feel confident that all technical problems have been dealt with effectively. At this point, around March 15, we will begin the systematic testing of the volunteer subjects.

PROJECT V - SMOOTH MUSCLE ACTIVITY AS RECORDED BY RADIO TELEMETRY

Investigator - Kenneth R. Simmons, Assistant Professor, Department of  
Animal and Dairy Science

Progress Report - February 1, 1966

Objectives. The objectives of this project were:

1. To develop radio telemetry techniques for monitoring and measuring smooth muscle activity.
2. To test improved transmitting devices for smooth muscle electromyography. These devices were to be constructed by the Department of Electrical Engineering of the University of Vermont.
3. To use these devices and techniques to measure smooth muscle activity primarily in domestic animals.

Procedure of Work. The smooth muscle system to be studied was the uterus. Rabbits were used as the experimental animal. Techniques learned with rabbits were to be applied to cattle and sheep. The areas of investigation were:

1. To adapt a transmitter, originally designed for ECG transmission, to smooth muscle myography.
2. To determine the proper type of electrodes and the best method for implanting these electrodes in the uterine myometrium.
3. To determine how long electrodes could be left in the muscle and still give an accurate interpretation of action potentials.
4. To determine the best location for electrodes, a location that would be most representative of overall uterine activity.
5. To compare results of this investigation with more conventional methods of recording uterine activity; i.e. electrical activity of individual fibers in situ or in vitro; the mechanical activity of the myometrium.
6. Then to record uterine activity, via radio telemetry, during different physiological (hormonal) conditions, as during the estrous cycle, gestation, and parturition.

Progress Report:

Most previous investigations of uterine electrical activity have been carried out on isolated strips of muscle suspended in a bath. Also, most studies have dealt with the activity of single cells, by the use of intracellular electrodes. There are very few studies of the electrical activity of uterine muscle in situ so there was little information with which to

compare our results. Consequently most of our studies were conducted on the intact uterus exposed so that gross muscular activity could be observed.

Work to date has been concerned with comparisons between direct recording and recording via radio telemetry, electrode location, and types of electrodes.

In order to have some understanding of the signals received and recorded from the ECG transmitter it was necessary to compare these signals with those received by direct recording. This has been the most recent phase of the project to be undertaken, and consequently it has not been completed. In general, however, it appears that the ECG transmitter gives a pattern that is similar to the pattern recorded directly. However, the radio transmitted pattern does not display the sensitivity of the other, i.e., it does not show the slow oscillatory type of electrical activity associated with a quiescent uterus. It would detect and transmit the action potentials of increased uterine activity or the bursts of action potentials that occur when waves of muscle contractions passed by the areas of the electrodes. Only a few attempts were made at measuring the intensity or frequency of these transmitted action potentials, and no definite conclusions can be reached.

Some of the previous investigations of uterine electrical activity have reported the presence of a pacemaker region either at the ovarian or cervical end of the uterus, with waves of contractions generally originating from these regions or have only detected them under certain physiological conditions such as shortly before parturition. In this investigation using non-pregnant rabbits, no pacemaker region was noted. Contractions were random and could originate at any point in the uterus.

This randomness of contraction presents a problem as regards to the location of electrodes. If a distinct pacemaker region could be found in the nongravid uterus, it would provide an excellent location for the electrodes. However, where there are apparent differences in frequency of contractions between different uteri, one area appears as good as another for the location of the electrodes within an individual uterus. Varying distances between electrodes along the length of the uterus is also under investigation.

Surface type electrodes do not appear to be practical for prolonged recording in situ. Loops of wire, passed through the myometrium, have been used as electrodes, but this has not proved entirely satisfactory. In some cases it has been impossible to say that the myometrium was the only tissue contacted. Very small loops, sutured in place in the myometrium, are currently being used. This type of electrode appears to be much better than any type previously used.

No recordings have been made under varying physiological conditions as yet, although this was the next step planned for the investigation.

A more sensitive transmitter would be desirable, but personnel changes in the Electrical Engineering Department have temporarily halted any work on the development of transmitters.

Continued work on this project should yield information on the activity of the uterus in situ. This information would be valuable in studies of sperm and ovum transport, fertilization mechanism, early embryo mortality, gestation and parturition.

PROJECT VI - DISTRIBUTION AND PHYSIOLOGICAL EFFECTS IN BRAIN OF CURRENTS  
FROM EXTERNAL ELECTRODES

Investigator - Stanley Rush, Associate Professor, Department of Electrical  
Engineering

Progress Report - February 1, 1966

Introduction

The program for studying the physical factors determining the current density field in the brain resulting from current introduced on the skull surface has been initiated in four areas. These are: (1) Studies of the current density field employing models in which human skulls are immersed in a conducting solution. The exterior is bounded by insulation representing the air-scalp boundary and the conducting solution represents the scalp and brain. (2) Detailed investigations of skull thickness and resistivity as they vary in different parts of the head. (3) Theoretical analyses of current fields in idealized models approximating the electrical properties of the head. (4) A general investigation of skull thickness as a function of age and sex.

1. Study of Current Density Field

The principal effort in this portion of the program has been so far concerned with the devising, purchasing, and debugging of instrumentation for plotting the current density fields. A three dimensional stereotaxic device has been purchased and mounted for controlling and measuring the position of the exploring probe. A sensitive bridge-type potential measuring system has been put together with special attention to grounding and shielding problems. A differential potential measurement is required with separate ground to prevent stray ground currents from flowing through the potential measuring electrodes. A digital voltmeter is used for rapid data taking. A constant current signal source is employed to minimize the effects of electrode resistance variations and to provide a system which can be directly converted to measurements on human subjects. Skulls have been purchased for the program and techniques for cutting them along lines of symmetry have been devised. The fabrication and instrumentation of the casing around the skull was worked out using a clay layer over the skull representing the scalp. The latter is then covered with plaster of paris which upon removal is lined with fiberglass to form a receptacle for the skull and conducting solution. The fiberglass is pierced with a grid of silver wire electrodes. The latter are required since the movable probe cannot reach below the skull itself to measure scalp potentials. One set of very preliminary measurements along the plane bisecting the skull vertically has been carried out. The general pattern seems to be satisfactory and useful results with the final refined system are anticipated within the next month.

2. Thickness and Resistivity Measurements

The method of measuring the resistivity of the skull sections has been completely worked out. Small rectangular segments have been cut from many areas of a sample skull and milled to fit tightly across a rectangular trough of conducting fluid. These pieces are previously soaked in a mild formaldehyde

solution for nine (9) days or more to fully absorb as much fluid as possible. The period required was ascertained from a series of resistance experiments extending over two weeks or more during which the segments' resistivity was followed as the bone absorbed more and more fluid. The formaldehyde is employed as it was found after a long period of investigation of anomalous effects that in an ordinary salt solution, a fungus grows in the skull and affects its resistivity determination. The skull resistivity is quite variable and is of the order of 100 times the resistivity of the fluid which permeates its pores.

### 3. Theoretical Studies

Three models have been considered. The analysis of the simplest of these a sphere (brain) surrounded by two concentric shells of different conductivities (skull and scalp) with diametrically opposed point current electrodes on the outside surface of the outer shell, has been completed. The second model is similar to the first but will be extended for any electrode placement on the scalp. This model has only been investigated so far as to determine that a solution is possible by the method of separation of variables. The third model is similar to the last but the spherical boundaries are replaced by confocal prolate spheroids. This analysis has been initiated and appears feasible.

### 4. Skull Thickness Investigation

This investigation has been started with an extensive literature search using the medical library and informed consultation with university staff members in several departments. The results of this investigation have only revealed so far that there is no data available on this subject; probably because there is no convenient technique. This suggests that the present investigation may be applied as a simple technique for skull thickness measurements. Fortunately, the Anatomy Department has a substantial collection of skulls with their histories, and some of the data sought will be obtained by the direct measurements of this collection.

## PROJECT VII-A - BIOENERGY ELECTRICAL SOURCES

Investigator - Wilfred Roth, Professor, Department of Electrical Engineering

Progress Report - February 1, 1966

### 1. Purpose

Electronic devices that can be implanted in living organisms such as heart pacemakers, telemetering transistors, and the like, require a source of electrical energy. The present state of the art requires that small dry cell batteries be used. The life of such energy sources varies from hours to several years depending upon the application.

Since the energy levels of various functioning parts of the body are sufficient to supply the required power for many implantable electronic devices, this research project is concerned with methods for converting this energy into electrical form to permit the elimination of short life batteries.

### 2. Progress from April 1965 to February 1966

A study of numbers of possible mechanisms for deriving electrical energy from the functioning animal or human was made. Consistent with the objective that the method used should be capable of an operating life time in the order of ten years, when implanted, numbers of approaches that are presently being worked on elsewhere were rejected in favor of a method wherein part of the energy of respiration is tapped and converted into electrical form. The initial work involved utilization of the intrapleural pressure variation.

By means of a fluid filled bladder attached to the pleural side of the diaphragm, a fluctuating pressure source was established. The fluctuating pressure was rectified by means of fluid check valves connected in a full-wave bridge configuration to produce a unidirectional static pressure head of approximately 1.5 PSI. This static fluid pressure source was then converted to a high frequency oscillating pressure (in the order of 1000 cycles per second) by means of a regenerative fluid flip-flop. The high frequency fluid pressure variations were sensed by a piezoelectric transducer whose alternating output was rectified by means of semiconductor components to develop DC electrical power.

By early fall, the basic elements of this system were assembled so that overall characteristics could be studied. Efficiency of the flip-flop was extremely low and power output below one microwatt was obtained. Matching of hydrodynamic impedance levels at the interfaces between the full-wave hydraulic rectifier, the flip-flop, and the piezoelectric transducer presented many problems because the fluid flip-flop impedance was far too low for our intended purpose. A study of the literature of such devices indicates that orders of magnitude of state of the art advance is needed before this embodiment of our bioenergy electric source can be utilized. As a consequence, this approach was tabled.

The method being studied now substitutes a mechanical oscillator for the fluid oscillator described above. The fluctuating intrapleural pressure is rectified by a mechanical linkage winding a spiral spring. This device is similar to that employed in self-winding watches. The potential energy stored by the wound spring is converted to oscillatory kinetic energy by virtue of an escapement mechanism driven by the wound spring. Oscillation occurs at approximately 30 cycles per second. Oscillations of the escapement drive a piezoelectric transducer whose output is rectified and filtered to produce the final DC power output. The major elements of the system are similar to those discussed above, but a mechanical analog of the fluid flip-flop is substituted.

Mechanical elements for the first experimental model using this approach are being assembled to permit studies of efficiency, power levels, etc.

### 3. Plans for the Future

Oversize models of the mechanical components required to implement the spring energy storage and oscillator will be constructed. When the system characteristics on the oversize models are thoroughly understood, miniaturization design efforts will be initiated directed toward the achievement of small, high efficiency, implantable units.

**PROJECT VII-B - RADIOLOGICAL DATA PROCESSING - CONTRAST DEMARCATION  
AND MULTICOLOR PRESENTATION**

Investigator - Wilfred Roth, Professor and Chairman, Department of  
Electrical Engineering

Progress Report - February 1, 1966

**1. Purpose**

The interpretation or "reading" of radiographs can be a difficult matter when fine structure and subtle details are of interest. Skilled observers can disagree about the interpretation of a radiograph. In an attempt to more fully utilize the senses of a skilled observer, conversion of black and white radiographs into multiple color displays is being investigated. The color vision sense of a normal observer is presently not utilized and we wish to determine whether color conversion will permit the observer to elicit more information than he can from a black and white radiograph.

**2. Progress from June 1965 to February 1966**

A standard commercial color TV receiver was purchased to serve as a final display means. A commercial black and white TV camera was borrowed from the Department of Radiology, Mary Fletcher Hospital, and it has been used to produce video output signals from a scanned black and white radiograph.

The video signals are fed into an electronic encoder that was developed during the summer. The encoder separates the entire black and white signal range capability of the TV camera into three separate ranges on the basis of optical density. After full electronic manipulation of the three separated signal channels, the respective signals are employed to modulate the red, blue and green guns of the picture tube in the receiver. As a consequence of this process, the conversion from varying density grey, from black to white, to variable hue is achieved.

The full color display of a black and white radiograph makes a striking impact on the observer but it is still too early to draw any conclusions with respect to the ability of the observer to "read" more information out of the display than he can out of the black and white radiograph.

**3. Plans for the Future**

Modification of all electronic circuits is underway in order to extend the bandwidth and, thereby, to improve resolution. The performance of the commercial TV receiver leads to degradation of the display so that even the black and white TV display is inferior to the original black and white radiograph. Difficulties have been experienced with the TV camera with respect to the limited dynamic range. Steps to improve this limitation will also be taken.

When performance of the color system is sufficiently improved, equipment will be duplicated for installation in the Mary Fletcher Hospital, Department of Radiology. At this time, subjective comparison of color display versus black and white display will be made in an attempt to evaluate whether the use of the color sense of the observer is advantageous.

(Photos included in Copy 1 only).

Figure 1. Display of radiograph on TV screen  
in black and white.

Figure 2. Display of same radiograph on color  
TV screen after signals from TV camera  
are operated on by encoder to convert  
varying shades of gray to color scale.

## PROJECT VIII - COMPUTER APPLICATIONS IN CLINICAL PATHOLOGY

Investigator - Rex D. Couch, Assistant Professor, Department of Pathology

Progress Report - February 1, 1966

This project has shown considerable activity in a number of areas in the past year. As will be noted with individual aspects of the project below, a part-time programmer was added, and two student trainees worked under NASA support. In addition, the relationships of this project have been developed further with other departments in the University, especially Electrical Engineering and Mathematics.

Various programs for analysis of clinical Chemistry data have been developed and have become extremely useful. The quality control statistical program is de-bugged and can be run without operator intervention. With a few minor changes it will be run on the IBM 1130 system, when delivered. Two programs, now being run in parallel have provided a lot of information about Chemistry data that is being used in a third area. Having had results from the Chemistry statistical program and the limits evaluation program for several months we have formed hypotheses that are being tested by a normal values program that utilizes probability theory to arrive at a decision boundary between normal and abnormal values. We observed that there were definite differences in the distributions of bilirubin values between infants and adults. This difference is now being studied and indicates the test is an entirely different one applied to infants and adults. This is the first objective proof of a belief that has developed among clinical pathologists in recent years. The results of this study, along with normal values for other liver function tests, will hopefully be submitted for publication this spring.

The input systems for Chemistry, Bacteriology, and Hematology are now operational. An ancillary study is being carried out with two residents in Pathology to gather data on battery testing. The concept of unsupervised machine learning for grouping of abnormal data is being developed by Dr. Lai, and the data derived from the battery tests (15 Chemical, 6 Hematologic, plus Urinalysis) will be input for this program. The normal values program output has been utilized for the program now being written to test for usefulness indices. These indices will be calculated for any laboratory test in any disease or diseases. This one-dimensional case will then be expanded to calculate the usefulness index for a group of tests in any number of diseases. The logical results, and our ultimate goal for this series of programs, will be calculation of disease loci in an n-dimensional system by means of laboratory values.

A specialized instrument for capture of Autoanalyzer signals, calculation of values from an internally integrated curve, and direct transmission to a keypunch machine has been developed jointly with Dr. Reed Williams and Mr. Harry Pendleton of the IBM Corporation. This will be installed within the next month. Interestingly, similar instruments are now being considered for marketing by IBM nationally, and is being marketed under the trade name "PACE" by the Electronics Associates, Incorporated.

As an outgrowth of this project, a study is being initiated by Drs. Fred Evering and Wilfred Roth of the Electrical Engineering Department and Dr. Jackson J. Clemmons of the Department of Pathology. Their study will develop a new approach in utilizing radioisotopes for measurement of various substances in Chemistry.

The IBM 1130 computer will be utilized for further development of programs and concepts already mentioned, and is also to serve as an initial tool in systems engineering for time-sharing applications. It is anticipated that additional personnel will be made available for continuance of the latter study.

The personnel now associated with the project include the principal investigator, co-principal investigator, two programmers, two input clerks, two summer student trainees, as well as residents in Pathology. Because of the interest of students and residents in this project it has been necessary to limit the number of persons we can help to train. It is hoped that other sources and personnel can be found in order to eliminate this limitation. This aspect of training interested individuals is extremely important and one of the most interesting and challenging ones we have experienced. The interest and support of persons from other University departments and administration have been extremely gratifying and have contributed greatly to any small success the project may have had.

#### Publications

Lindberg, D.A.B., Van Peenen, H.J., and Couch, R.D. Patterns in Clinical Chemistry. Low serum Sodium and Chloride in Hospitalized Patients. Am. J. Clin. Path. 44:315-321, 1965.

Couch, R.D.: The Role of Computers in Small Hospitals. A Look into the Future. Read at the New England Post-Graduate Assembly, November 5, 1965.  
Submitted for publication.

## PROJECT IX - DIMENSION-THEORETICAL ASPECTS OF METRIZABILITY

Investigator - Bruce R. Wenner, Assistant Professor, Department of Mathematics

Progress Report - February 1, 1966

The first objective of this project was to determine whether a Nagata metric necessarily has a dimension-preserving completion. This problem is near solution at this time, and may be completed within the month. The problem in separable metric spaces had already been solved by the principal investigator in the spring of 1965, and it remained to solve the more general case of arbitrary metric spaces.

A Nagata metric on an  $n$ -dimensional space  $R$  is one which has the following property:

For any  $\varepsilon > 0$  and any  $x \in R$ , the boundary of the  $\varepsilon$ -sphere  $S_\varepsilon(x)$  about  $x$  has dimension  $\leq n-1$ .

This can be generalized to a  $\sigma_f$ -space as follows:

Let  $R = \bigcup_{i=1}^{\infty} R_i$ , where each  $R_i$  is closed and is of finite dimension  $n_i$ . Then a Nagata metric on  $R$  has the following property:  
for any  $\varepsilon > 0$ , any  $x \in R$ , and any natural number  $i$ , the boundary of  $S_\varepsilon(x)$  meets  $R_i$  in a set of dimension  $\leq n_i-1$ .

J. Nagata has shown that any finite-dimensional metric space admits a topologically equivalent Nagata metric, and the principal investigator has shown that a metric  $\sigma_f$ -space also has this property. The metric is introduced by using a uniformity which has the right properties to exhibit the space's covering dimension, and the metric is then defined on this uniformity. The principal investigator has recently shown that the uniformity can be strengthened in a way such that the resulting metric  $d$  on a  $\sigma_f$ -space  $R = \bigcup_{i=1}^{\infty} R_i$  has the following property:

for any  $n_k+2$  points  $y_1, \dots, y_{n_k+2}$  of  $R_k$  such that

for all  $i \leq n_k+2$ ,  $d(S_{\varepsilon/2}(x), y_i) < \varepsilon$  for some

$x \in R_k$ , then  $d(y_i, y_j) < \varepsilon$  for some  $i \neq j$ .

By using this theorem it seems almost certain (the principal investigator is presently cleaning up the details of the proof) that the completion with respect to this metric does not raise dimension.

This tells us that if a Nagata metric has been constructed from the particular uniformity in question, its completion does not raise dimension on any of the subspaces  $R_i$ . The only remaining problem then is to determine whether an arbitrary Nagata metric must necessarily have the same property. It seems that it must, but this remains to be proved (it does not promise to be difficult). The procedure would be to construct a new, equivalent Nagata metric by going back to the metric uniformity and strengthening it. The completion with respect to the new metric does not raise dimension, as has already been shown, but the completion with respect to the old metric is homeomorphic to it and hence must also preserve dimension.

## PROJECT X - CHANGES IN NUCLEOLAR ULTRASTRUCTURE RELATED TO PLANT DEVELOPMENT

Investigator - Beal B. Hyde, Professor and Chairman, Department of Botany

Final Report - February 1, 1966

In September 1965 I received \$3,000 from an institutional NASA Grant (NGR-46-001-008) Project 10, to purchase a single piece of equipment. This piece of equipment - a Kinney Vacuum Evaporator KSE-2 - has been purchased and installed and is performing excellently. The small balance remaining in the grant at this writing will be exhausted when Buildings and Grounds submits their bill for installation.

This evaporator is an essential adjunct to an electron microscope laboratory. It is used for two main purposes. First, we prepare films on copper grids to support biological specimens observed in the electron microscope. Second, we may evaporate (shadow) metals or alloys on small objects such as viruses or macromolecules for the purpose of electron microscope observation. It is, of course, possible to use it for a variety of purposes where a vacuum of the order of  $1 \times 10^{-5}$  Torr. is desired. In the present project it is being used for the former purpose. The machine is a permanent part of the electron microscope laboratory being assembled in the Botany Department.

Although this is a final progress report for the NASA support, the project is only in its inception. The necessary equipment has been assembled for about 4 months. At present four people are working part time. The senior investigator, Dr. A. Gershoy, Emeritus Professor of Botany, Dr. Louise Raynor, Associate Professor, and Stephen Blackwell on an NSF Undergraduate Research Participation program.

So far, all three parts of the project submitted have been initiated. The first part, preparation of anthers of P. ovata during the prophase of meiosis for E.M. observation, has been carried the farthest. Some electron micrographs have been taken. It is clear that some improvement in fixation or embedding must be made before critical micrographs of nucleolar fine structure during these stages can be made. However, the techniques have been worked out in a general way and have proved to be feasible.

The second aspect of the project -- the study of the changes in the nucleolus which accompany the deposition of protein in the P. ovata embryo -- is still in the light microscope survey stage. It will be necessary to learn the general character of the embryonic development by doing some histochemistry on these young embryos and ovules. Dr. Raynor, the local expert on plant embryology, has been brought into the project for this purpose.

The third aspect of the project is being carried out largely by Mr. Blackwell in cooperation with Dr. Sproston and his group. This aspect concerns the fine structural changes in the growing hyphae of Alternaria, a fungus, after it has been induced to sporulate. We have just about solved the technical problems of growing and preparing this fungus for E.M. work. By the end of the semester we should have some electron micrographs of this fungus and should be able to define more precisely the limits of this problem. Considering the relatively short period over which the project has been active, it is felt that a substantial beginning has been made on a broad front.

## PROJECT XII - CALCULATIONAL AND EXPERIMENTAL ASPECTS OF ENTROPY DETERMINATIONS

Investigator - Claus A. Wulff, Assistant Professor, Department of Chemistry

Progress Report - February 1, 1966

### Calculational:

(1) The estimation of inorganic entropies - The most common need for an estimated entropy of an inorganic substance is in the calculation of free-energies and equilibrium constants from enthalpies of formation. The necessity of refined estimates may be inferred from the fact that an entropy uncertainty of  $\pm 1 \text{ cal deg}^{-1} \text{ mole}^{-1}$  corresponds to a 20% uncertainty in a room temperature equilibrium constant. Of several estimation methods that have been advanced, that developed by Latimer is deservedly the most popular; and generally reproduces experimental entropies within  $\pm 3 \text{ cal deg}^{-1} \text{ mole}^{-1}$ . The Latimer method is simply additive - summing entropy contributions for each ionic constituent of the compound. It is largely empirical and is, therefore, in constant need of revision as more data become available.

During this past semester, this author has considered the following two schemes. The first is a revision of Latimer's additivity constants bases on the new data that have appeared since the last revision in 1952. For most substances entropies calculated using such new constants are only slightly more accurate than those calculated from Latimer's original values. The second method has been derived to take advantage of observed linear correlations between entropies and enthalpies of formation.

If we assume for the compound MX(c) that

then 
$$\Delta S_f = \alpha + \beta \Delta H_f, \quad \dots\dots\dots(1)$$

$$S_{MX} = S_M + S_X + \alpha + \beta \Delta H_f \quad \dots\dots\dots(2)$$

$$S_{MX} = S'_M + S'_X + \beta \Delta H_f(MX). \quad \dots\dots\dots(3)$$

The combination of equations similar to (3) and for the compounds MX, MY, NX, NY leads to

$$\frac{(S_{MX} - S_{MY}) - (S_{NX} - S_{NY})}{[\Delta H_f(MX) - \Delta H_f(MY)] - [\Delta H_f(NX) - \Delta H_f(NY)]} = \beta \dots\dots(4)$$

Using literature values for entropies (S) and enthalpies of formation ( $\Delta H_f$ ) several values of  $\beta$ , in satisfactory accord, were calculated. Equation (3) may be inverted to read

$$S'_M + S'_X = S_{MX} - \beta \Delta H_f(MX) \quad \dots\dots\dots(3')$$

With the value of  $\beta$  obtained from equation (4) the sum  $S_M' + S_X'$  can be evaluated. Since the individual additivity contributions have no physical significance, an arbitrary value was assigned to  $S_K'$  and all values for other species were calculated relative to this assigned value.

Additivity contributions developed in this manner reproduce experimental entropies significantly better than does Latimer's method. For example, 63% of the calculated entropies for halides and sulfates of univalent metals fall within the uncertainty of the experimental values; and the r.m.s. deviation for bivalent metal compounds is  $1 \text{ cal deg}^{-1} \text{ mole}^{-1}$  less than that obtained using Latimer's method.

These calculations are essentially complete. The necessary  $\Delta H_f$  input data were taken from NBS Circular 500. This publication is now being revised and has been published in part. Final revision and submission for publication of the entropy estimation scheme will await comparison of the input data used and the revised NBS values. It is not anticipated that drastic revision will be necessary, and the project should be complete by March 1966.

(2) The entropies of aqueous ions - (In conjunction with Professor Loren G. Hepler, Carnegie Institute of Technology, Pittsburgh, Pa.). For many of the transition metal elements, entropies of their inorganic compounds are lacking. To provide input data for the scheme, outlined in (1) above, it was necessary to compute several entropies from solution thermochemistry and equilibrium data in the literature. Also necessary for the calculations are the partial molal entropies of the aqueous ions.

Literature data pertinent to such calculations for the aqueous  $\text{Zn(II)}$ ,  $\text{Cd(II)}$ ,  $\text{Hg(I)}$ , and  $\text{Hg(II)}$  ions have been collected and several independent paths to each partial molal entropy have been followed. The resultant entropies seem considerably more reliable than existing literature values, and have been used to calculate a self consistent set of entropies for the halides and sulfates of these elements.

These results have been written up and submitted for presentation at the National Meeting of the American Chemical Society in March 1966. Shortly prior to the meeting the paper will be submitted for publication to the Journal of Chemical and Engineering Data.

Calculations based on literature data and experimental results (obtained at Carnegie Institute of Technology) have been completed to yield partial molal thermodynamic data for the aqueous  $\text{Co(II)}$  and  $\text{Ni(II)}$  ions and the entropies and heats of formation of their sulfates. These results have been accepted for publication by the Journal of Physical Chemistry.

Similar entropy evaluations for other transition metal ions are now underway.

(3) The evaluation of barrier heights - A calculation of the height of the potential barrier hindering internal rotation of the methyl groups in hexamethylbenzene has been initiated using the low-temperature heat-capacity results of J. G. Aston, et al. It was felt that a simple extension of the treatments used for methyl-, dimethyl-, and trimethylbenzene would be applicable but the results were discouraging. It became evident that a new treatment of the lattice vibrations was necessary, and several such refinements have shown promising results. A preliminary estimate of the barrier height shows it

to be much greater than those in the related compounds studied previously.

### Experimental

A graduate student, Mr. John Lerbscher (B.S. - Franklin and Marshall College), has been added to the group. He has begun research on the equilibria of ion-pairs in solution, to provide the necessary free energy data to calculate the partial molal entropies of these interesting species. His present investigations are concerned with solutions of  $\text{Ca}(\text{OH})_2$ ,  $\text{Ba}(\text{OH})_2$  and  $(\text{NH}_4)_2\text{SiF}_6$ ; the ultimate aim being to determine the entropies of the aqueous  $\text{CaOH}^+$ ,  $\text{BaOH}^+$ , and  $\text{SiF}_6^{-2}$  ions.

Equipment to be used with the low-temperature cryostat has been ordered. The blueprints for the cryostat itself are not yet complete, but it is anticipated that they will be available this spring.